PB90-221896

Evaluation of HCl Measurement Techniques at Municipal and Hazardous Waste Incinerators

Entropy Environmentalists, Inc., Research Triangle Park, NC

Prepared for:

Environmental Protection Agency, Research Triangle Park, NC

1990

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before complet

1. REPORT NO.	2.	3.
EPA/600/D-90/031		PB90-221896

4. TITLE AND SUBTITLE
Evaluation of HCl Measurements Techniques at Municipal and Hazardous Waste Incinerators

5. REPORT DATE

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)

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8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

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Research Triangle Park, NC 27711

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO.
68-02-4442

12. SPONSORING AGENCY NAME AND ADDRESS
U.S. Environmental Protection Agency
Office of Research and Development
Atmospheric Research and Exposure Assessment Laboratory
Research Triangle Park, NC 27711

13. TYPE OF REPORT AND PERIOD COVERED

14. SPONSORING AGENCY CODE
EPA/600/09

15. SUPPLEMENTARY NOTES
Publication in AWWA Proceedings of the Specialty Conference on Continuous Emission Monitoring - Present & Future Applications, Chicago, IL, Nov. 12-15, 1989

16. ABSTRACT

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The EPA has sponsored several field tests to assess the performance of commercially-available HCl continuous emission monitoring systems (CEMS's) and a proposed manual sampling and analysis methodology for use at municipal and hazardous waste incinerators. Tests were performed (1) to determine the capability of HCl CEMS's to provide valid measurement data, (2) to develop HCl CEMS performance specifications, and (3) to develop a suitable performance test method.

This paper reviews findings obtained during previous tests conducted at the municipal waste combustors, and presents new results acquired during field evaluations at a hazardous waste incinerator.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL INFORMATION SERVICE
SPRINGFIELD, VA. 22161

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Release to Public	Unclassified	14
	20. SECURITY CLASS *(This page)*	22. PRICE
	Unclassified	

PB90 221896/AS

EPA/600/D-90/031

EVALUATION OF HCl MEASUREMENT TECHNIQUES AT MUNICIPAL AND HAZARDOUS WASTE INCINERATORS

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This paper reviews findings obtained during previous tests conducted at the municipal waste combustors, and presents new results acquired during field evaluations at a hazardous waste incinerator.

Introduction

Hydrogen chloride (HCl) emissions from hazardous waste incinerators (HWI's) are regulated by the U. S. Environmental Protection Agency under Subpart O of 40 CFR 264. The HCl emission limit for HWI's is expressed as a mass rate of 4 pounds per hour or 1% of the HCl entering the pollution control equipment. The EPA is currently developing a New Source Performance Standard (NSPS) for HCl emissions at municipal waste combustors (MWC's); several states and local agencies have already set HCl standards for MWC's. The control technology exists to reduce the HCl emissions produced by the incineration of municipal and hazardous wastes, but until recently, techniques to adequately quantify the HCl in the effluent using either instrumentation or wet-chemistry sampling methods have not been evaluated.

Carbon monoxide (CO) is currently the only gas constituent for which continuous emission monitoring is required under Subpart O. CO monitors are used to demonstrate compliance with permit limits and indicate proper operation of the incinerator. The EPA may require HCl monitoring at these facilities after HCl continuous emission monitoring systems (CEMS's) have been demonstrated to be reliable. The HCl data are intended to be used in the same manner as the CO CEMS data. Some states will require HCl monitoring at MWC's either to demonstrate emission levels or control efficiency; the EPA will propose use of sulfur dioxide CEM data as a surrogate for HCl monitoring.

An EPA HCl test method has not yet been promulgated. The currently accepted HCl method employs a modified version of a Method 5 sampling system. Water or a dilute alkaline solution, such as sodium hydroxide, are used to absorb the HCl which is then analyzed by titration or ion chromatography. This method has been used for HCl tests to demonstrate compliance with the incinerator performance standards. The method determines total chlorides and does not speciate HCl and chlorine (Cl_2). An EPA performance test method free of interferences, such as Cl_2, is needed for incinerator performance tests and for HCl CEMS accuracy tests.

In 1986, the Quality Assurance Division (QAD) of EPA's Atmospheric Research and Exposure Assessment Laboratory (AREAL) initiated evaluation efforts related to the measurement of HCl. The EPA has sponsored several field projects to evaluate the performance of commercially-available HCl CEMS's and a proposed manual method. The purpose of the field tests was to provide data on the performance characteristics of HCl CEMS's and to formulate appropriate HCl CEM performance specifications. Laboratory and field testing was also performed to develop and evaluate the proposed manual sampling and analysis methodology for the determination of HCl emissions.

The EPA evaluated several potentially applicable CEM measurement techniques and sampling equipment. Manufacturers of the HCl monitoring equipment were contacted to arrange the loan of equipment for the evaluations. Seven HCl analyzers, utilizing four different detection techniques, and four sampling systems were evaluated. Two analyzers were designed for ambient air application and thus did not come equipped with a sample handling system.

The proposed HCl test methodology is based on a modified Method 6 protocol for sampling and ion chromatography for analysis. The configuration of the impinger train and the reagents used allow speciation of HCl and Cl_2, thus providing HCl data free of Cl_2 interference.

The performance evaluations were conducted at three MWC's and one HWI. The MWC's are mass-burn incinerators that receive municipal solid waste from residential and commercial sources. Two of the MWC's were equipped with a spray dryer absorber (SDA) and either a baghouse or electrostatic precipitator (ESP) control system for acid gas and particulate removal. The HWI consisted of a fixed hearth primary chamber and a secondary chamber designed to combust solid and liquid hazardous waste. An SDA and baghouse were installed as pollution control equipment.

The average effluent conditions encountered during these tests were 10-100 ppm HCl and 40% moisture at the HWI, 200-500 ppm HCl and 15% moisture at the MWC control equipment inlets, and 5-50 ppm HCl and 20% moisture at the MWC control equipment outlets.

Monitoring System Descriptions

The Bodenseewerk 677 HCl analyzer employs the gas filter correlation (GFC) technique and a multiple pass optical cell and sampling system maintained at 180°C (356°F). The analyzer contains a correlation wheel that consists of two hemispherical cells, one filled with HCl and the other with N_2. Passing the IR beam through the HCl gas filter produces a reference beam that cannot be further attenuated by HCl in the sample gas. The N_2 side of the filter wheel is transparent to the IR radiation and therefore produces a measurement beam that can be absorbed by HCl in the cell. Other gases do not cause modulation of the detector signal because they absorb the reference and measurement IR beams equally. Thus, the GFC system responds specifically to HCl. The Model 677 analyzer employs zero air and an internal sealed gas cell for zero and upscale calibration checks. The sample gas is drawn from the stack via a heated sample pump at a rate of approximately 13 L/min. The monitoring system can accept calibration gases at an injection point located in the probe.

The Thermo Environmental (TECO) monitoring system is comprised of a Model 15 GFC HCl analyzer whose measurement principle is identical to that of the Bodenseewerk 677. The Model 200 dilution system is employed to provide a sample to the analyzer with a moisture content below the moisture dew point. The sampling system consists of an in-situ dilution probe with sample orifice, transport tubing, and a probe control unit. The dilution probe, using dry instrument air at approximately 40 to 60 psi, allows the sample to be diluted and transported under pressure to the analyzers. A vacuum of 17.5 in. Hg is created downstream of the critical orifice with an aspirator driven by the dilution air. A constant flow of flue gas sample is drawn through the orifice, mixed thoroughly with the aspirator air, and transported through the sample line to the analyzer.

The sampling system is designed to permit various dilution ratios within the probe by selection of the appropriate orifice. Orifices rated for 150 and 500 mL/min sample flow were used during the tests to provide dilution ratios of 40:1 and 12:1, respectively. Calibrations are performed by introducing calibration gas through a Teflon transport line to a point within the probe upstream of the dilution orifice.

The Bran & Luebbe Ecometer operating principle is based on potentiometric measurement using a Cl^- ion-selective electrode. A stainless steel and Teflon probe, heat-traced Teflon line, and diaphragm pump are employed to transport the gas sample from the stack to the analyzer at a flow rate of approximately 1 L/min. The gas sample is kept at a temperature of approximately 200°C during transport. The flue gas sample is mixed with an absorbing solution within the analyzer, resulting in the absorption of HCl and the formation of Cl^- ions. The absorbing solution containing the Cl^- ions is degassed and conveyed to the ion-selective electrode to be quantified.

The Ecometer performs an internal calibration during which sampling is stopped and two calibration solutions are fed in sequence to the ion-selective electrode. The calibration results are stored in a microcomputer, and used in the calculation of stack gas concentrations. The probe was modified prior to the test program so that calibration gas could be injected into the sampling system.

The Compur 4150 HCl analyzer uses a Cl^- ion electrode to measure HCl. The measurement principle is identical to the Bran & Luebbe. The analyzer performs an internal calibration using liquid standards. The calibration results are used in the calculation of sample concentrations. A Compur Model 4330 dilution system employs a dilution probe that provides constant sample gas dilutions at selected ratios. The Compur dilution system operation is identical to the TECO 200 system. Calibration of the system is performed by injecting calibration gas in the probe at a point upstream of the critical orifice.

The MDA 7100 analyzer detection technique is colorimetric-based. Sample gas is drawn into the analyzer at a constant rate. The HCl in the sample reacts with chemicals impregnated on the paper tape, and forms a colored stain with an intensity proportional to the HCl gas concentration. An electro-optical sensing system reads the stain and produces a signal that is then compared to calibration values stored in the analyzer's microcomputer, and a concentration is determined. The flue gas sample and calibration gases were provided to the MDA by either the TECO 200 or Compur dilution systems.

The CEA Instruments TGM-555 analyzer is an automated wet-chemical colorimetric analyzer. Sample gas is drawn into the analyzer and contacted with an absorbing solution. The chemical reaction of the HCl in the gas sample with the absorbing solution produces a color change in the solution. The colorimeter measures the light absorption of the reagent before and after reaction. The intensity of the color is directly proportional to the concentration of HCl.

The CEA TGA-410 analyzer measures HCl using a gas membrane galvanic cell sensor. The cell consists of two electrodes immersed in two electrolyte solutions. The HCl in the gas sample is absorbed into the electrolyte solutions within the cell, causing equivalent oxidation-reduction reactions to occur. Two electrodes of opposite polarity create an electron flow and produce a concentration-related current.

Draft Manual Method Equipment Description

The draft HCl test method (Proposed Method 26) uses a modified EPA Method 6 protocol for sampling, and ion chromatography for analysis. The

sampling system is illustrated in Figure 1. The configuration of the HCl sampling train includes a glass probe, midget impingers in an ice water bath, and a meter box equipped with a pump and gas metering devices.

The sampling train was comprised of an empty knockout impinger for effluent moisture, followed by two impingers containing 15 ml of 0.1 N H_2SO_4, one impinger containing 15 ml of 0.1 N NaOH, and one impinger containing Drierite. A meter box equipped with a small diaphragm pump, flow control valves, a rotameter, and a calibrated dry gas meter was used to measure the gas sample volume pulled through the impinger train.

A heated glass sampling probe was used to provide gas sample to the impinger train. An in-stack filter employing a 25 mm Teflon-coated glass mat filter with a 99.5% DOP rating for 0.3 micron particles (Pallflex TX40HI75) was placed at the inlet of the glass probe liner and secured with a Teflon compression union.

The midget impinger train was connected to the probe outlet using a heat-wrapped three-way glass stopcock. This stopcock permitted the sampling probe to be purged with stack gas prior to collecting samples. A purge line was attached to the third leg of the three-way valve. The purge line included a drying tube, rotameter, and small diaphragm pump. The probe and stopcock were purged with flue gas for five minutes immediately prior to sampling.

The impinger samples were analyzed by ion chromatography. The non-suppressed IC was performed with a Perkin-Elmer Series 10 pump, a Rheodyne Series 7010 sample injection valve, a 100 x 4.1 mm Hamilton PRP-X100 anion column, and a Milton Roy detector with a temperature-controlled conductivity cell. The eluent was 4 mM potassium hydrogen phthalate at a flow rate of 2 mL/min. An electronic integrator was used to produce chromatograms and provide integration of the Cl^- peak area. The system was calibrated before and after each analysis. A spreadsheet program was used to calculate the calibration line, sample results, and flue gas HCl concentrations.

CEM Performance Test Procedures

Three performance tests were used to evaluate the HCl CEMS's at the incinerators. The tests were relative accuracy, calibration error, and calibration drift.

The relative accuracy test was used to validate the CEMS calibration technique and verify the ability of the CEMS to provide representative and accurate effluent measurements. The test was performed following the procedures outlined in 40 CFR 60, Appendix B, Performance Specification 2. It involved comparison of the CEM data to concurrent measurements obtained using the proposed EPA test method. The relative accuracy calculation is based on the assumption that the manual method provides reference measurements that are representative of the source emissions. The average HCl flue gas concentrations (dry-basis) determined by the manual method and the HCl CEMS during the same time period were compared. Flue gas water vapor was also collected by the manual method sample train and quantified gravimetrically on site. Water vapor results were used to correct the wet-basis CEMS measurements to a dry basis so that a direct comparison could be made to the dry-basis reference measurements. Test run durations varied from 20 to 60 minutes. The manual samples were collected from a probe positioned near the CEM probes.

The calibration error test served to demonstrate the linearity of the CEMS over the entire measurement range. It involved the injection of zero air and at least two cylinder gases into each CEMS. Each monitor was operated in its normal sampling mode. Calibration gases were injected at the sample probes so that they passed through all components of the sampling system. The duration of each gas injection was sufficient to assure that adsorption/desorption reactions on the CEMS surfaces had stabilized. The calibration gas values and the corresponding instrument responses were compared. The response time was also documented during these gas injections.

The calibration drift test documented the stability of the CEMS calibrations over time by injecting zero air and HCl calibration gas once each day. The gases were introduced into the sampling system at the probe so that the gas passed through all components of the sampling system. This check was repeated periodically during the field test. Drift was determined by comparing CEMS responses to calibration gas values.

Results and Discussion

CEM Performance

The initial field test was an evaluation of the CEMS's for measurement of uncontrolled HCl emissions at an MWC.[1] This test provided baseline performance data that were used to identify CEM operational problems and determine what equipment may not be suitable for continuous source emissions measurement.

All of the tested analyzers, except the CEA TGA-410 analyzer, indicated the same trend in the HCl concentrations, typically 200-500 ppm, and produced data that were in good agreement with the wet-chemistry results. The CEA analyzer did not respond to any changes in the gas concentration and was removed from the evaluation.

At the beginning of each relative accuracy test period, all CEMS's were calibrated to the same HCl gas standard. The Bodenseewerk CEMS exhibited a $\leq$20% relative accuracy for all four tests. Each of the other analyzers showed a $\leq$20% relative accuracy for three of the four tests.

The calibration error tests were performed using zero air and two upscale HCl calibration gases. The Bodenseewerk and TECO CEMS's produced results that were all $\leq$2.0% of span. The MDA and LSI results were excessive due to nonlinearity associated with the measurement techniques of these two analyzers. The Compur experienced problems in producing repeatable responses to each set of gas injections.

Daily calibration data were compiled to show the general drift characteristics of the analyzers. The results for the Bodenseewerk and TECO were all within 1.5% of span. The data indicate that the MDA and Compur analyzers may have difficulty maintaining daily drift within the 2.5% of span limit normally required for CEMS's.

The response times of all the CEMS's, with the exception of the CEA TGM-555, were within 15 minutes.

The Compur CEMS, CEA TGM-555, and MDA analyzers experienced numerous operational problems during the initial field test. The Compur problems were associated with the analyzer, not the sampling system. The Compur CEMS was returned to the vendor to resolve the problems, and was not returned for subsequent evaluations. The CEA analyzer was dropped from the evaluation because the response time of the analyzer was extremely slow, and the measurement output was nonlinear. The MDA analyzer had difficulty producing repeatable results to calibration checks, but remained in the test program.

The CEM performance evaluation was continued at two MWC's with installed HCl emission control equipment to evaluate the CEM measurement of controlled levels of HCl.[2] Two short-term field evaluations were conducted; one involving the Bodenseewerk CEMS, and the second involving the TECO, MDA, and the newly acquired Bran & Luebbe CEMS. The HCl CEMS's were installed and operated continuously for approximately one week at locations downstream of the HCl control equipment. The TECO sampling system was operated using the dilution probe with a dilution ratio of 12:1. Two relative accuracy tests were conducted on each CEMS.

Agreement between the Bodenseewerk and TECO CEMS measurements and the reference values was excellent (within 2 ppm HCl). The effluent HCl levels ranged from 3 to 30 ppm.

A consistent negative bias of approximately 60% was observed in the Bran & Luebbe CEMS measurement. The mean differences, however, for the two tests were -2.7 and -5.7 ppm HCl. Prior to these tests, the Bran & Luebbe CEMS was calibrated using the liquid standard. The calibration was not checked with HCl calibration gases because of CEMS design limitations at the time of testing. Gas injections might have helped identify possible causes of this bias in the measurement. The sample probe has since been modified to allow calibration gas injections through the entire sampling system.

The TECO sampling system was used to supply diluted sample gas to the MDA analyzer. The analyzer failed to respond to HCl in the effluent sample, although it responded well to the 18 and 47 ppm HCl calibration gases. The minimum detection limit for the MDA was checked in the laboratory and found to be approximately 1 ppm. The diluted HCl concentration in the effluent sample delivered to the MDA by the TECO dilution system was generally less than 1 ppm.

Graphic comparisons of effluent HCl levels measured at an MWC by the CEMS's and the draft manual test method are presented in Figures 2 and 3. The limited testing for controlled, or low level HCl emission measurements at MWC's has shown that the Bodenseewerk, TECO, and Bran & Luebbe CEMS's performed well. The three CEMS's operated continuously without problems during the one-week tests.

The Bodenseewerk, Bran & Luebbe, and TECO CEMS's were then selected for a six-week evaluation at an HWI facility.[3] The CEM samples were obtained from the incinerator stack downstream of the pollution control equipment. Difficult aspects of CEM operation were revealed at the HWI that were not encountered during the MWC tests. Despite the difficulties, brief periods of concurrent CEM operation provided comparative CEM measurements. Figure 4 presents a comparison of the three CEMS effluent measurements.

The TECO dilution probe experienced plugging problems that were attributed to the condensation of organics within the aspirator in the probe. A TECO representative later explained that this problem can occur if the effluent contains high levels of sulfuric acid or hydrocarbons. Mixing sample gas with cooler dilution air within the aspirator apparently caused some organics to condense and plug the aspirator nozzle, which resulted in the loss of sample drawn through the orifice. The aspirator was easily cleaned by flushing the probe with acetone. The probe operated well after the dilution air was preheated to a temperature above 200°F. However, by this time the TECO 15 analyzer had been returned to the vendor for repair of an electronic problem.

The performance of the Bran & Luebbe CEMS was adversely affected by the undesired formation of silver iodide on the Cl^- ion electrode tip. Iodine, in some form in the effluent sample, reacted with silver chloride in the absorbing solution and produced a film that coated the electrode. This caused the CEMS to produce erroneous calibration and effluent measurements, and increased response time. Cleaning the electrodes provided short-term resolution of the problem. This explanation of the problem was not provided until the field test was completed and the electrodes were sent to the vendor for investigation. Bran & Luebbe now uses special calibration and absorbing solutions for HWI applications that prevent the silver iodide from interfering with the HCl measurements.

The Bodenseewerk CEMS operated continuously without malfunction during the six-week period. All three performance tests were conducted on the Bodenseewerk. The results indicate that this system performed well. Accuracy of the CEM data could not be properly determined because the data handling configuration of the Bodenseewerk CEMS was not appropriate for the HWI effluent conditions.

Bodenseewerk calibrates each instrument at the factory using HCl calibration gases blended with water vapor at the average concentration expected at the particular source. Although HCl measurements are made on a wet basis, this factory calibration correction provides instrument readings that correspond to a dry measurement. The Bodenseewerk CEMS used in this evaluation had been set up for an average effluent moisture content of 15%. However, the effluent moisture content at the HWI incinerator (30 to 40% by volume) was significantly higher than the 15% correction performed internally. During the field test, a volume adjustment was made to the Bodenseewerk CEMS calibration and effluent measurements to remove the 15% moisture correction, and thus provide measurements that may reflect actual sample conditions (i.e., wet-basis). This volume correction alone may not be appropriate for the effluent measurement data. It is not known how the effluent measurement readings of a CEMS configured for 15% water vapor are affected when the water vapor in the sample is significantly different than 15% by volume.

A calibration error test was performed using four HCl calibration gases with concentrations within the Bodenseewerk CEMS 0-250 ppm measurement range. The Bodenseewerk CEMS response time during the gas injection tests was 3 minutes. The responses were adjusted to remove the 15% moisture correction. The maximum deviation between the gas value and corresponding instrument response was 3 ppm, or 1.2% of full scale.

The calibration routine using zero air and the internal gas-filled cell (47 ppm HCl) was performed daily. The maximum daily zero and upscale calibration drift observed throughout the test period was 3 ppm, or 1.2% of full scale.

Calibration gas was injected periodically into the Bodenseewerk CEMS to verify the internal calibration results. Concentrations of the HCl calibration gases used to perform this check ranged from 36 to 69 ppm HCl to demonstrate accuracy near the 47 ppm HCl internal cell value. Zero air and one HCl gas were each injected into the probe at about 13 L/min. The maximum deviation between the gas values and the observed responses was 3.5 ppm, or 1.6% of full scale. Agreement between the results obtained by the two calibration techniques was excellent and consistent with the results obtained during the tests conducted at the MWC's.

Manual Test Method Performance

Laboratory and field studies were performed to develop and evaluate a sampling and analytical technique for measuring HCl from stationary sources.[4,5] Studies were conducted in three phases: (1) literature search and development of a candidate sampling and analysis protocol, (2) laboratory evaluation and refinement of the protocol, and (3) field evaluations at an MWC and an HWI. A modified Method 6 sampling train was selected for sample collection due to its ease of operation, availability, and cost. A 0.1 N H_2SO_4 absorbing solution was used for collecting HCl in the impingers. The 0.1 N H_2SO_4 impinger solution was selected to minimize the interference for diatomic chlorine (Cl_2) during analysis. Ion chromatography was selected as the most suitable technique for the analysis of HCl.

The sampling trains were challenged with various concentrations of HCl and Cl_2 at different flow rates to evaluate the ability of the absorbing solution to efficiently collect and speciate HCl in the presence of Cl_2. A minimum sampling rate of 2 L/min was found to reduce the HCl measurement bias caused by Cl_2. This value was less than 5% for the tested Cl_2 levels up to 50 ppm. A 99% HCl collection efficiency in the first impinger was also obtained at this sapling rate.

Accuracy of the combined sampling and analysis protocol was estimated employing 30-minute test runs consisting of dynamic spiking of the sampling trains with HCl cylinder gas. The average relative error was 5.5% and 7.1% for HCl gas mixtures of 10 and 34 ppm, respectively.

Tests for precision involved paired impinger train sampling. The average precision (expressed as the relative standard deviation) of the sampling protocol was 6.2% at an average flue gas HCl concentration of 4 ppm, and 3.2% at an average concentration of 15 ppm. The average relative standard deviation for the moisture determination employing the midget impinger train was 4.5% and 3.2%, respectively, at the same concentrations.

Additional testing was performed to compare the HCl results from the draft HCl protocol to those obtained using a Method 5-type sampling train employing an alkaline impinger reagent. The Method 5-type sampling system results were biased approximately 10% lower relative to the midget impinger results. The cause of the bias has not yet been identified.

The midget impinger and Method 5-type sample results were not affected by the choice of quartz or Teflon filter media. Also, flue gas CO_2 absorbed by the alkaline impinger reagents was found to be insignificant in the midget and Method 5-type sample trains. The method is insensitive to slight changes in reagent volume, impinger pH, sampling time, impinger temperatures, and sampling rate that may occur during actual use. The method, as described, may also be suitable for determining Cl_2 emissions.

Conclusions and Recommendations

A midget impinger train employing an acidified impinger reagent and operated at a sampling rate of 2 L/min provides acceptable HCl collection efficiency at HCl levels up to 500 ppm and is not susceptible to significant Cl_2 interference at Cl_2 levels less than 50 ppm. The precision and bias demonstrated for the HCl method are acceptable, and the method can also be used for moisture determination.

The field evaluations of the HCl monitoring equipment at the MWC's and the HWI identified difficulties associated with the CEM measurement and the interpretation of CEM performance at the low HCl levels.

The Bodenseewerk, Bran & Luebbe, and TECO CEMS's provided similar indications of change in the HCl effluent concentrations at the MWC's and the HWI. However, only the Bodenseewerk performance was consistent throughout the CEM evaluations conducted at the MWC's and the HWI. The composition and conditions of the HWI effluent provided a greater challenge to the TECO and Bran & Luebbe CEM operation than the MWC's. Successful sampling of HWI effluent with an in-stack dilution probe is dependent upon the acid and organic constituents in the sample and the temperature of the aspirator air relative to the effluent temperature. A specially formulated absorbing solution must be used in the Bran & Luebbe when operated at an HWI. The Bodenseewerk CEMS internal correction for water vapor in the sample should be eliminated to provide HCl measurements at actual sample conditions.

The Compur, MDA, and CEA monitors were removed from the evaluation because of unacceptable performance.

The issue concerning CEM data accuracy needs further investigation before formulating a relative accuracy specification for HCl CEMS's. The results of accuracy assessments of HCl CEMS's measuring controlled emissions can be difficult to interpret. The emission levels tend to be less than 50 ppm at incinerators that employ HCl removal equipment, which causes the relative accuracy calculations using a percent of the mean reference values to become unnecessarily restrictive. The relative accuracy test is limited to the concentration levels occurring during the tests. A relative accuracy test at low levels may not reflect the accuracy of the analyzer at the level of the emission standard, which may be significantly higher. Additional testing at an HWI is recommended to:

- Determine Bodenseewerk performance with proper calibration values for sample gas moisture content.
- Determine TECO performance with a sampling system that prevents orifice plugging.

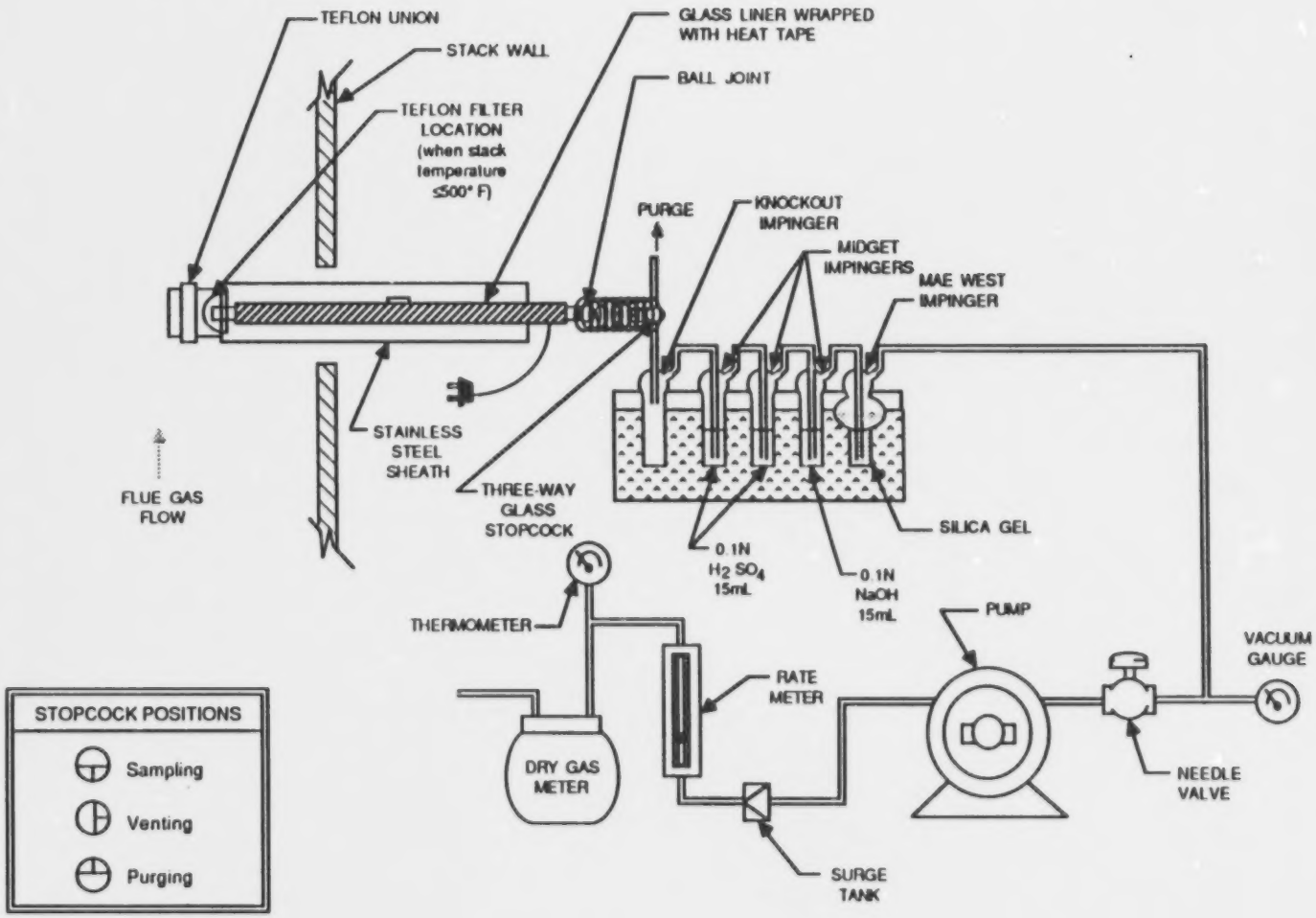

Figure 1. Proposed Method 26 HCl sampling train.

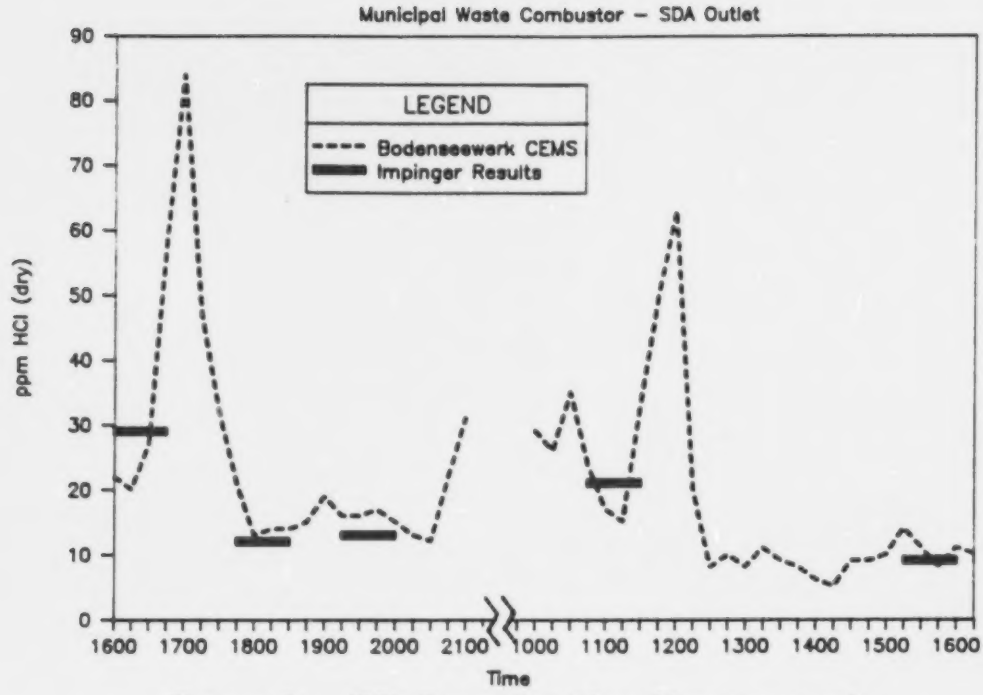

Figure 2. HCl Concentration Measurements

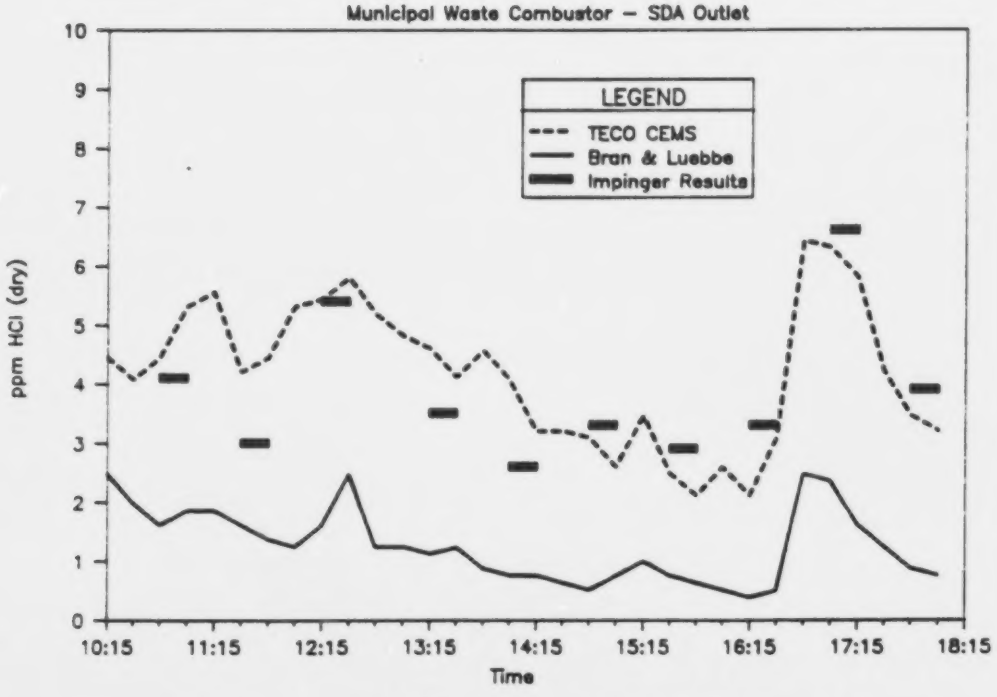

Figure 3. HCl Concentration Measurements

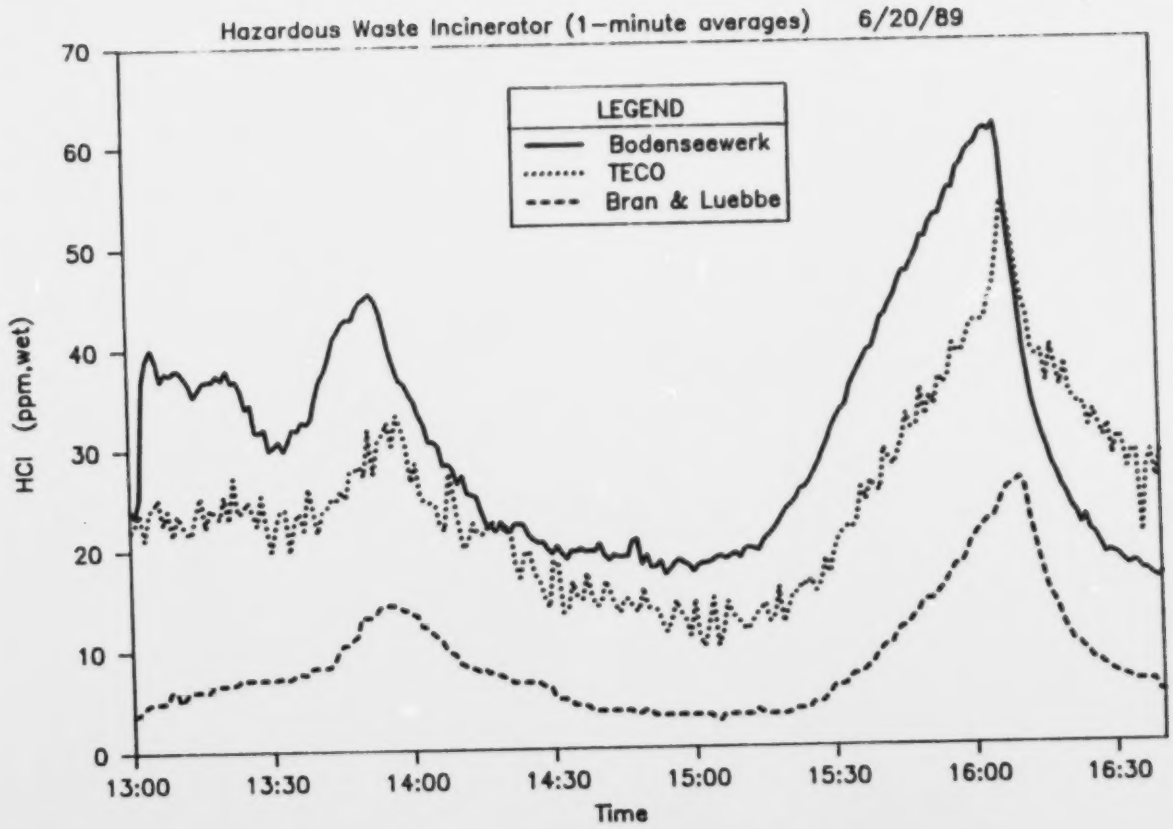

Figure 4. HCl CEMS Data Comparison

- Determine Bran & Luebbe performance with an absorbing solution that prevents silver iodide formation on the electrodes.

- Determine the relationship between HCl calibration gas injection results and relative accuracy results. The cylinder gas audit procedure outlined in 40 CFR 60 Appendix F, Procedure 1 could be used in lieu of the relative accuracy test to estimate CEM accuracy.

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